SURVEILLING THE ASSETS

Craig Watterson and David Wavell, Expro Meters, UK, explain how emergent non-intrusive flow metering technology is adapting to diverse environments and applications, and becoming an important tool for production surveillance.

Upgrades and modifications to existing surface infrastructure is a constant requirement in the energy industry to maintain required operational and safety standards. Operators must balance the requirement for upgrades with the cost of deferred production during shutdown periods.

The repair and/or replacement of inline flow metering can be a costly undertaking, with the majority of expense typically attributed to the cost of the metering hardware. However, this can be equalled and sometimes overshadowed by the cost of engineering documentation, management of change requirements, upgrades to cabling and data acquisition/SCADA systems and deferred production related to process shutdown during flowmeter installation and maintenance.

One route to reducing cost and time is using a flowmeter that can be retrofitted and commissioned on existing piping infrastructure, without disruption to ongoing operations.

By design, Expro's non-intrusive clamp-on PassiveSONAR™ and ActiveSONAR™ flowmeters can be installed on existing pipework with no process shutdown and minimal management of change costs. The sonar technology's flexibility means that the flowmeter can be applied in a variety of monitoring applications.

Tracking vortical structures

Sonar array processing is used in flow measurement to determine the rate at which naturally occurring flow turbulence, known as coherent vortical structures, travel past an array of sensors. These coherent vortical structures are created by the flow in a pipe, due to the pipe wall shearing mechanism inherent in virtually all flow streams. These structures maintain their characteristic shape, or are coherent, for a sufficient flow length (20 - 40 pipe diameters) to allow them to be tracked as they pass through a sensor array. The speed at which these vortical structures pass through the array is a direct indication of volumetric flowrate (Figure 1).

Tracking of the flow-generated vortical structures through the sensor array is accomplished by looking at the relationship between the spatial wavelength (distance) and temporal frequency (time) of sensor signals. Sonar processing looks at the spatial wavelength/temporal frequency over a range of values, which are typically determined based on flow velocity and pipe size.

Two different methods of sonar flow measurement have been developed, PassiveSONAR and ActiveSONAR flowmeters. These are analogous to passive and active underwater sonar methods.

PassiveSONAR in underwater acoustics uses an array of hydrophones and listens passively to the sounds generated by objects. In flow measurement, the meter utilises a passive array of strain-based sensors clamped-on to the outside of the pipe. These sensors listen to the strain generated by the naturally occurring flow turbulence. These signals are amplified and processed using sonar to determine the flowrate of the medium in the pipe.

In underwater acoustics, when the object does not generate sufficient sound for the PassiveSONAR flowmeter to detect it (run silent/run deep), an ActiveSONAR flowmeter is used. This is where a sound source transmits a signal that reflects off the object and is then received by the hydrophone array. Likewise, ActiveSONAR flowmeters utilise an active array of sensors clamped-on to the outside of the pipe. The sensors transmit a signal through the flow medium to a receive sensor at the opposite side of the pipe. The received signals are amplified and signal processed using sonar to determine the flowrate of the medium in the pipe.

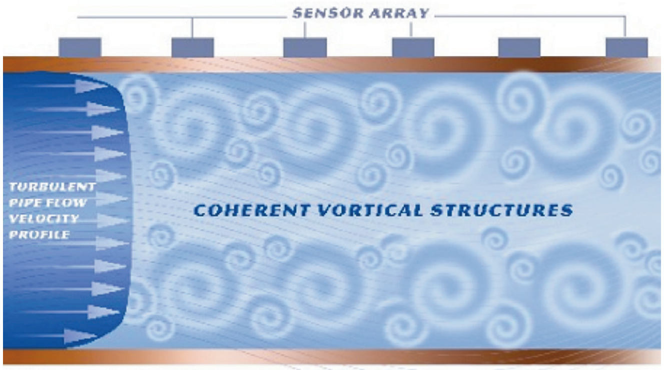

Figure 1. *Vortical structures pass through sensor array.*

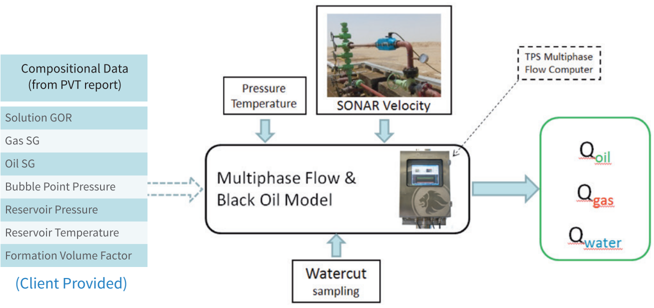

Figure 2. *TPS platform using SONAR multiphase surveillance.*

Figure 3. *SonarMonitor™ - permanent monitoring.*

A unique measurement device

There are a number of flowmeter technologies and models available to the oil and gas industry. Choosing the correct one depends on a number of variables and often comes down to factors such as total installed cost, accuracy and repeatability in what are typically multiphase conditions. Options range from traditional differential pressure meters like orifice or venturi type meters, to inline multiphase flowmeters (some of which use nuclear sources), non-intrusive, cost-effective clamp-on devices.

Expro's sonar meters fall into the non-intrusive, clamp-on category; however, they are differentiated from clamp-on ultrasonic meters in that the inherent measurement principal, sonar, is a completely different approach to flow measurement.

Ultrasonic flowmeters rely on time-of-flight or 'Doppler' effects. These clamp-on ultrasonic meters have been used successfully in single-phase applications; however, those technologies can be challenged by thick pipes and multiphase conditions typically seen in oil and gas.

Sonar meters, by contrast, use the phase modulation caused by the naturally occurring vortical energy of the flow itself. This allows measurements to be made when mixed or multiphase flow regimes are present – an environment very common upstream of separation devices in the oil and gas industry, and especially common immediately downstream of a wellhead.

Total production surveillance

Sonar meters measure the velocity of the mixture flowing through the pipe. For reservoir surveillance at the wellhead, the typical requirement is to provide rates of individual phases – produced gas, oil/condensate and water. To provide these multiphase measurements, Expro Meters has developed the Total Production Surveillance (TPS) system for multiphase reporting of black oil (naturally flowing, electrical submersible pump, gas-lifted) and gas condensate production wells.

The TPS system leverages a combination of PVT models and multiphase flow correlations.

The TPS (TPS1000) System utilises PassiveSONAR and ActiveSONAR flowmeters (depending on the application) to clamp-on to wellhead piping to measure mixture volumetric flowrate at actual conditions. The measurement is then combined with process pressure, temperature and user-supplied compositional information to determine individual phase flowrates (Figure 2). This process is broadly applicable to a wide range of production and injection wells. The TPS1000 system can be applied on gas condensate, black oil production wells, gas-lifted black oil wells and black oil wells fitted with ESPs. The surveillance can be provided on a survey or permanent monitoring basis (Figure 3).

The TPS1000 system complements a programme of conventional well testing by offering a quick, reliable and cost-effective solution for applications requiring recurring production surveillance, especially where the reservoir conditions remain fairly stable over time.

Figure 4. *SonarTest™ - periodic surveillance.*

Flexible delivery

Each oil and gas producing region and asset differs in terms of accessibility and suitability for using equipment in the field. A single well pad in the Iraqi dessert requires a different platform for equipment supply than a normally unplanned installation (NUI) in the North Sea. In some cases, operators desire 24x7x365 flow measurement for reservoir surveillance, production allocation between partners or other drivers. In different cases, periodic well testing campaigns are sufficient to provide the data the reservoir technologist needs to optimise production and tune reservoir simulation models.

For periodic campaigns of production testing, Expro deploys its technology though a delivery model branded SonarTest™. This system deploys the company's sonar meter and technician on a rental basis. This configuration provides a production/injection well testing option for operators with multiple wells in remote locations or those that require frequent but periodic reservoir data, without the necessity for upfront capital expenditure. Additionally, it provides a mechanism for operators to verify existing metering to ensure valid flowrates are being reported. The deliverable to the client in this case is not hardware, but data, which is delivered to the client's desktop in the form of a SonarTest report.

As a permanent flow measurement device, Expro's sonar meters can be permanently installed on location and tied into facility data acquisition systems for continuous surveillance (branded SonarMonitor™). This becomes beneficial for locations where monitoring changes in individual well performance is critical to the management of the reservoir. The model also offers a non-invasive way of replacing existing meters that are not functioning or have fallen out of operating range due to production being off-plateau. Sonar meters can directly plug into the data acquisition/SCADA system in place of the replaced meter, with minimal change-management impact.

Profiling declining wells

A successful application of Expro Meters for individual well surveillance is ongoing on the Marathon-operated East Brae platform in the UK North Sea.[1] The SonarTest method provides a method for minimising losses associated with well testing and subsequent benefits with respect to production optimisation and well deliquification.

The platform has a high pressure (HP) separator 406 psig (28 barg) and a test separator operating as a low pressure (LP) production separator 217 psig (15 barg). There are currently 12 producing gas wells; varying water to gas ratios and low gas rates result in liquid loading being a major flow assurance issue.

Prior to sonar metering, wells capable of only flowing to the LP separator needed to be shut-in to allow individual well tests. Wells can now be individually sonar well tested without production interruption. Different methods have been adopted to optimise production and combat liquid loading.

'Swing' wells use the LP separator to unload liquids and thus improve their subsequent performance in the HP separator. Sonar metering determined the optimal cycle frequency for individual wells, allowing the operator to keep the separator full and maintain maximum rates in the HP separator. This intensive well management has assisted in reducing the production decline of the East Brae field.

Field-wide surveillance

The first successful field-wide surveillance for the technology was Centrica Energy's operated North and South Morecambe Fields, which are among the largest in the UK Continental Shelf in terms of original reserves.[2]

Monitoring real time production surveillance rates from each well in the field provides critical information for reservoir management and workover planning. Centrica explored the range of potential replacement technologies for the existing venturi meters, including installing new inline differential pressure meters of several types, as well as traditional ultrasonic type meters. Parameters considered include the cost of acquisition, installation and the total cost of ownership, measurement quality and repeatability. Turndown ratio, or the instrument's measurement range, was also an important consideration as this instrument was expected to measure well production throughout the declining life of the field.

In 2010, an Expro meter was trialled on one well to assess its applicability to the well conditions in the Morecambe fields. The flowmeters were subsequently installed on all 44 producing wells across six platforms. Sonar meters clamped onto the existing pipework allowed installation without shutting in the well (and incurring the associated lost production) reducing management of change and HSE exposure.

Sonar well tests, which were undertaken on all wells after installation and commissioning, are an important tool in understanding the allocation from each individual well. Since there is no shutdown time, the production losses are significantly lower compared to separator testing as each individual well would need to be diverted to the separator.

With the installation of sonar flowmeters, production teams were able to benefit from the availability of real time flow information for each well. Following the start-up of a new, HP field, wells on one of the platforms had reduced in performance. Sonar flowmeters were used to establish the worst affected wells, along with those that would respond well to a cycling procedure.

The decision was made to have a particular well shut in for an hour each day, in order to help unload liquid in the tubing and achieve slightly higher flowrates from the well. The benefit was observed almost immediately, with peak flowrate almost doubled. Further shut in lengths and/or frequencies were trialled on the well until an optimum operating routine was established.

Zero flaring

A prevalent environmental consideration is the effect of hydrocarbon flaring from production testing operations, which causes pollution and results in significant production losses. Equally, the measurement of net oil rate from individual wells is a critical component in effective oilfield management influencing production optimisation strategies.

Equipment commonly used in the field for production testing operations is the mobile conventional well test separator (CST), where both oil and gas are diverted to a flare pit and burned into the atmosphere. The industry has now begun to move towards 'zero flaring' to significantly reduce both pollution and cost by allowing the recovery of production losses.

Zubair Field Operating Division (ZFOD) and Eni Iraq BV explored methods to reduce flaring.[3] Expro assisted in altering production testing activities in order to achieve 'zero flaring' status.

The technology's non-intrusive, multiphase tolerant capabilities allowed production testing without the requirement for the mobile CST. The sonar meter clamps on to the existing production flowlines without the requirement to divert flow or stop production. Leveraging the TPS system and black oil models, this method was able to report oil, gas and water rates from 269 naturally flowing and ESP-lifted black oil wells between 2011 and 2013. This approach contributed to saving 2.5 million t of CO_2.

Moving away from the wellhead

The sonar meter's functionality at the wellhead is a clear benefit for operators to understand how their wells produce. However, the technology in terms of both design and measurement principles, make it suitable for a wider variety of applications. These include, but are not limited to, injection monitoring, drilling mud measurement, pipeline leak detection, separator outlet measurement, cavern storage and large diameter export pipeline measurement.

Reservoir pressure support plays an important role in production optimisation, and injecting the appropriate amount of water and/or gas is vital in prolonging the life of a reservoir. Understanding injection cycles and rates play a key role in reservoir management.

Sonar meters are applied to injection measurement whether the injection method is water, gas or water alternating gas (WAG). In addition to injection wells designed for pressure support, the sonar meters are operable with high CO_2 content in injection gas and are used on CO_2 disposal wells and miscible gas injection projects.

Measurement of drilling mud requires a solution which is in the first instance, safe, but can also withstand the high pressures and harsh environments inherent in all drilling operations. Traditional methods are often challenged by this. The robust design, clamp-on nature and insensitivity to cuttings and entrained gas in liquid flows make it ideally suited to measuring both mud flows into and out of the well. Sonar meters can be applied to both conventional and managed pressure drilling operations.

Entrained gases are often encountered in the liquid leg of gas liquid separator based measurement approaches and, if unrecognised, can result in significant error in net oil.[4] Sonar meters are installed on the liquid leg of a two- or three-phase separator to provide a real time, entrained gas measurement using the gas void fraction function of the PassiveSONAR meter. This additional function of the meter works in parallel to its volumetric flowrate capability.

Flow monitoring for large diameter pipelines using inline flowmeters can be a challenging and expensive task, especially where legacy metering requires repair and replacement, and where large diameter pipelines with high value hydrocarbon product need to shutdown for extended periods. Sonar meters have been applied to a 30 in., 1 in. thick export pipeline flowing 1 billion ft^3/d of gas.[5] The non-intrusive installation provided a total cost saving to the client of US$1 million because there was no requirement for process shutdown.

Loading of shuttle tankers that receive cargo from large export flowlines on floating production storage offloading (FPSO) vessels and platforms can be a concern where rupture of transfer umbilicals is a possibility. Following such an incident in Norway, sonar meters were selected as the preferred measurement device for a leak detection system on the cargo lines of shuttle tankers for their ease of installation, accuracy and cost.[6]

Conclusions

This emergent non-intrusive clamp-on surveillance tool is seeing increasing industry acceptance for applications throughout the well lifecycle. The design, ease of installation and standard communication protocols render the meters both diverse in delivery and in application range – reflecting the industry's need for flexible technology that meets evolving requirements.

Furthermore, the technology's clamp-on nature allows convenient retrofit installations to existing infrastructure. Its tolerance to multiphase flow in addition to the TPS solution, make it ideally suited to wellhead production monitoring. The flexibility of rental and purchase options also gives users the ability to both verify and replace existing metering.

By providing robust production data on an individual well basis, meters are being used to assist operators in reservoir management and production optimisation. Away from the wellhead, Expro's sonar meters offer an alternative solution to traditional measurement methods in a number of different applications.

Looking to the future, metering technology will continue to deliver non-intrusive surveillance solutions that capture critical data and enable operators to make important decisions for the well lifecycle.

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